NATIONAL AERONAUTICS
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Reuse Readiness Levels (RRLs) – A Work in Progress

Software Reuse Working Group

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6th Joint ESDS Working Group Meeting

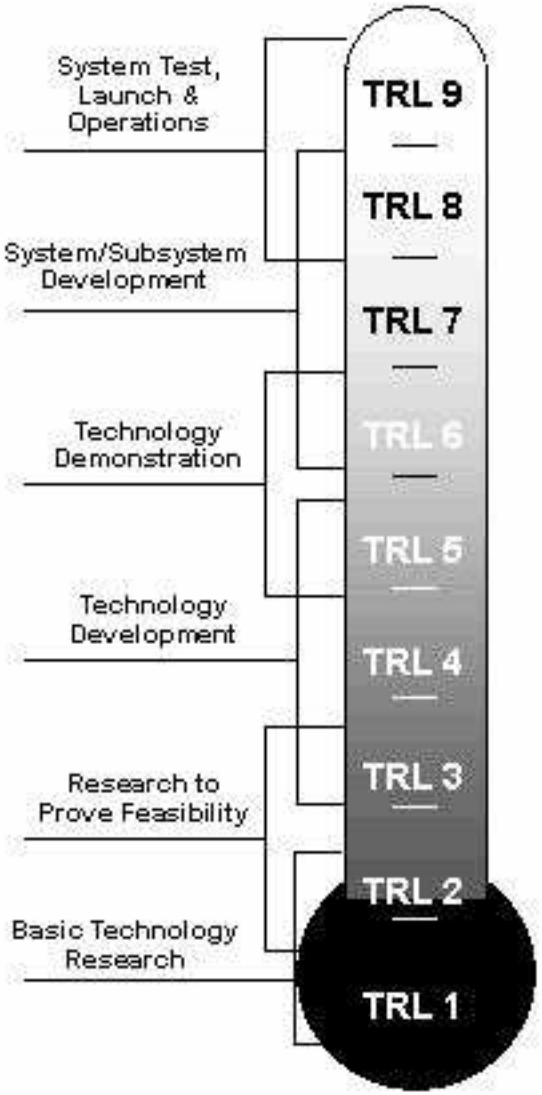
Background – TRLs

- Technology Readiness Levels (TRLs) and similar measures can be used to evaluate the maturity of a particular technology.
  - NASA TRLs range from 1 to 9, going from basic principles to mission proven.
  - While designed more for hardware, these have also been applied to software (see next slide).
- These measures typically do not consider reuse/reusability, or do so only in a limited manner.
  - The emphasis is the maturity of the technology as a whole.
  - The Open Process Framework's Technology Readiness Assessment is one of the few that includes reuse, but only in terms of reused critical technologies.

Technology Readiness Levels

Applied to Software

(v4 5/6/99)



TRL 9: Actual system "flight proven" through successful mission operations *Thoroughly debugged software. Fully integrated with operational hardware/software systems. All documentation completed. Successful operational experience. Sustaining software engineering support in place. Actual system fully demonstrated.*

TRL 8: Actual system completed and "flight qualified" through test and demonstration (Ground or Flight) *Thoroughly debugged software. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. V&V completed.*

TRL 7: System prototype demonstration in a space environment *Most functionality available for demonstration and test. Well integrated with operational hardware/software systems. Most software bugs removed. Limited documentation available.*

TRL 6: System/subsystem model or prototype demonstration in a relevant environment (Ground or Space) *Prototype implementations on full scale realistic problems. Partially integrated with existing hardware/software systems. Limited documentation available. Engineering feasibility fully demonstrated.*

TRL 5: Component and/or breadboard validation in relevant environment *Prototype implementations. Experiments with realistic problems. Simulated interfaces to existing systems.*

TRL 4: Component and/or breadboard validation in laboratory environment *Standalone prototype implementations. Experiments with full scale problems or data sets.*

TRL 3: Analytical and experimental critical function and/or characteristic proof-of-concept *Limited functionality implementations. Experiments with small representative data sets. Scientific feasibility fully demonstrated.*

TRL 2: Technology concept and/or application formulated *Basic principles coded. Experiments with synthetic data. Mostly applied research.*

TRL 1: Basic principles observed and reported *Basic properties of algorithms, representations & concepts. Mathematical formulations. Mix of basic and applied research.*

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References on TRLs

Here are links to a number of documents on TRLs and other measures:

- http://www.hq.nasa.gov/office/codeq/trl/trl.pdf
- http://esto.nasa.gov/files/TRL_definitions.pdf
- http://isd.gsfc.nasa.gov/Technology/TRL/TRL.ppt
- http://www.stsc.hill.af.mil/crosstalk/2005/05/0505Gold.pdf
- http://www.opfro.org/index.html?Components/WorkProducts/ArchitectureSet/TechnologyReadinessAssessment/TechnologyReadinessAssessment.html~Contents
- http://www.sei.cmu.edu/pub/documents/02.reports/pdf/02sr027.pdf
- http://csdl2.computer.org/comp/proceedings/hicss/2005/2268/09/22680315a.pdf and http://www.sei.cmu.edu/pub/documents/04.reports/pdf/04tr013.pdf
- http://www.iccbss.org/2004/proceedings/ImpACT.pdf
- http://www.openbrr.org/docs/BRR_whitepaper_2005RFC1.pdf
- http://www.hq.nasa.gov/office/codeq/trl/r&d3.pdf
- http://www.dtic.mil/ndia/2003systems/nolte.ppt
- https://acc.dau.mil/CommunityBrowser.aspx?id=25811

Introduction to RRLs

- The issue of how to measure the maturity of software, in a reusability sense, was discussed at last year's joint WG meeting.
- Having a measure of the reusability of an asset:
  - Provides potential reusers with additional information about the reuse maturity of the asset
    - Lets them know what they're getting
    - Gives them a basic feel for what modifications may be needed
  - Helps potential reusers make better informed choices about:
    - What to reuse
    - What best meets their needs
- *This measure can be used as a piece of metadata for assets placed in the RES (or anywhere else).*
- We have suggested the creation of a set of Reuse Readiness Levels (RRLs) to measure the maturity of a technology with respect to reusability.

Developing the RRLs

- Through discussions on weekly and monthly telecons, the Reuse WG made the following decisions:
  - To use nine levels, to align with the familiar TRL scale.
  - To look at nine topic areas that we felt were important for measuring the reuse maturity of software.
- Volunteers from the WG:
  - Wrote an initial set of levels for each topic (2+ people per topic) and
  - Drafted summaries of each RRL, looking at the levels for all topic areas.
- During the meeting, we have been discussing:
  - The level summaries, to determine what to use as the RRL scale, and
  - The longer descriptions for each level in the RRL scale.
- Follow-up after the meeting will include:
  - Completing the RRL discussion and writing a document on the RRLs
  - Publicize the RRLs (post on our web site, present at meetings, etc.)
  - Develop RRL calculator(s) where users can apply their own topic weights
  - Submitting the work to NASA HQ (and Standards WG?) as a recommendation

RRL Topic Areas and Levels

- Topic areas included:
  - Documentation
  - Extensibility
  - Licensing
  - Modularity
  - Packaging
  - Portability
  - Standards compliance
  - Support
  - Verification/Testing

- **Example from Testing/Verification**

RRL 4 – Software application tested and validated in laboratory environment

Following successful testing of inputs and outputs, the testing would include integrating an application to establish that the “pieces” will work together to achieve concept-enabling levels. This validation must be devised to support the concept that was formulated earlier and should also be consistent with the requirements of potential system applications. The validation is relatively “low-fidelity” compared to the eventual system: it could be composed of ad hoc discrete components in a laboratory; for example, an application tested with simulated inputs.

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Proposed RRL Topic Levels

	Portability	Extensibility	Documentation	Support	Packaging	Intellectual Property issues	Standards compliance	Verification & Testing	Modularity
Level 1	The software is not portable at any cost	No ability to extend or modify program behavior	Limited internal documentation available	No support available	Source code available	Potential owners and stakeholders of product have been identified.	Follows no particular standard	No testing performed	No designs for modularity or reuse
Level 2	Some parts of the software may be portable	Prohibitive costs and efforts need to modify or extend the system	Fully commented source code available	Known contact available		Relevant intellectual policies of potential owners and stakeholders have been reviewed.	Follows some parts of common standards and best practices	Software application formulated and unit testing performed	
Level 3	The software is only portable with significant costs	Can be extended with the input of considerable time and effort on par with recreating system separately	Basic external documentation available	Original developers provide proactive support	Detailed installation instructions available	Intellectual property agreements have been proposed to potential stakeholders.	Follows a company-wide standard for development and testing	Testing includes testing for error conditions and proof of handling input errors	Modularity at major system or subsystem level only
Level 4	The software may be portable at a reasonable cost	Can be modified and extended through configuration changes, minimal modification of source	Reference manual available	Latest updates or patches are available but not very frequently		Potential stakeholders have negotiated on intellectual property agreements and authorship issues.	Most components follow a complete, universal standard, but not validated	Software application demonstrated in a laboratory environment	
Level 5	The software is moderately portable	Consideration for future extensibility designed into system, extensibility approach somewhat defined	User manual available	Informal user community available	Software is easily configurable for different environments	Agreement and approval on authorship, attribution, and intellectual property issues has been obtained from stakeholders.	All components follow a universal standard, but only partially validated	Software application tested and validated in a laboratory environment	Partial segregation of generic and specific functionality
Level 6	The software is portable	Designed from the start to allow easy extensibility, provides many points of extensibility and a thorough and detailed extensibility plan	Tutorials available	Centralized support available		Authorship, attribution, and intellectual property statements have been drafted to reflect agreement among stakeholders on intellectual property and authorship.	Validated to follow a specific proprietary standard	Software application demonstrated in a relevant environment (Earth science related)	
Level 7	The software is highly portable	Proven to be extensible internally, code structured to provide loose coupling and high cohesion	Interface guide available	Organized/defined support by the original developer available	OS detect and auto-build for supported platforms	Authorship and intellectual property statements included in product prototype.	Validated to comply to a specific open standard	Software application tested and validated in a relevant environment (Earth science related)	Clear delineations of specific and reusable components
Level 8		Proven extensibility on a major external program, provides a clear plan for modifying and extending features	Extension guide and/or Design/Development guide available	Support by organization available		Manifestation of authorship, attribution, and intellectual property statements reviewed in product prototype before product release.	Proven by validation to comply with a “gold” standard	Software application "qualified" through test and demonstration (meets requirements) and successfully delivered to the Earth science environment	
Level 9	The software is completely portable	Proven extensibility in multiple scenarios, provides specific documentation and features to build extensions	Full software lifecycle engineering design documentation available	Large user community with well-defined support available	GUI installation environment provided	Reviewed authorship, attribution, and intellectual property statements packaged with product for release.	“Gold” standard compliance of entire system and development, independently validated	Actual software application tested and validated through successful use of application output	All functions and data encapsulated into objects or accessible through web service interfaces

These topic levels are the result of much work and discussion by the Reuse WG.

You will be able to read all of these levels on our poster this (Wed.) afternoon.

Reuse Readiness Levels – Documentation Topic

RRL	Level Summary
1	Limited internal documentation available
2	Fully commented source code available
3	Basic external documentation available
4	Reference manual available
5	User manual available
6	Tutorials available
7	Interface guide available
8	Extension guide and/or Design/Development guide available
9	Full software lifecycle engineering design documentation available

Reuse Readiness Levels – Support Topic

RRL	Level Summary
1	No support available
2	Known contact available
3	Original developers provide proactive support
4	Latest updates or patches are available but not very frequently
5	Informal user community available
6	Centralized support available
7	Organized/defined support by the original developer available
8	Support by organization available
9	Large user community with well-defined support available

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Reuse Readiness Levels – Intellectual Property Issues Topic

RRL	Level Summary
1	Potential owners and stakeholders of product have been identified.
2	Relevant intellectual policies of potential owners and stakeholders have been reviewed.
3	Intellectual property agreements have been proposed to potential stakeholders.
4	Potential stakeholders have negotiated on intellectual property agreements and authorship issues.
5	Agreement and approval on authorship, attribution, and intellectual property issues has been obtained from stakeholders.
6	Authorship, attribution, and intellectual property statements have been drafted to reflect agreement among stakeholders on intellectual property and authorship.
7	Authorship and intellectual property statements included in product prototype.
8	Manifestation of authorship, attribution, and intellectual property statements reviewed in product prototype before product release.
9	Reviewed authorship, attribution, and intellectual property statements packaged with product for release.

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Draft Reuse Readiness Levels

RRL	Level Summary
1	No reusability – software is not reusable
2	Initial reusability – software reuse is not practical
3	Basic reusability – software might be reusable by skilled users at substantial effort, cost and risk
4	Reuse is possible – software might be reused by most users with some effort, cost and risk
5	Reuse is practical – software could be reused by most users with reasonable cost and risk
6	Software is reusable – software can be reused by most users although there may be some cost and risk
7	Software is highly reusable – can be reused by most users with minimum cost and risk
8	Demonstrated reusability – software has been reused by multiple users
9	Proven reusability – software is being reused by many class of user over a wide range of system

Possible Discussion Points

- Do we have appropriate topics?
- Should we delete or add any topics?
- Do we have an appropriate number of levels?
- Should any levels be split up or combined?
- Any feedback about our initial combination into a single RRL scale?
- Are there quantitative measures for each level?